Title: A DNA barcode survey of marine macroalgae from Bergen (Norway).

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Abstract: Marine forests are ubiquitous to coastal systems across the globe and are becoming increasingly threatened by climate change. Safeguarding the services provided by marine forests inherently depends on an accurate understanding of macroalgal species diversity. Here, we provide the first DNA barcode survey of marine macroalgae from Norway, with a focus on the Bergen area, and compared our findings to morphological listings for the corresponding area (sector 8; marine area within Hordaland county) as provided by Brattegard & Holte (2001), with updates. Specimens were sampled April 14-20 and June 3-13, 2016, and variously sequenced for several genetic markers, including the five prime end of the cytochrome c oxidase subunit I gene (COI-5P), elongation factor *tufA* in Chlorophyta, and full or partial (three prime end) ribulose-1, 5-biphosphate carboxylase large subunit gene (*rbc*L or *rbc*L-3P). We generated 655 new barcode records for COI-5P, 11 for *tufA*, 41 for *rbc*L, and 9 for *rbc*L-3P, representing 51 species of Phaeophyceae, nine species of Chlorophyta, and 74 species of Rhodophyta. Sequence data confirmed 113 morphological species listed for the area. A further 17 genetic groups indicated the presence of new species for sector 8, only six of which were linked to formally described species. The remaining four genetic records were uncertain in terms of morphological species assignment and relation to previous sector 8 records. We recommend further DNA barcoding surveys in the area, as only a third of the listed morphological species were genetically confirmed.

Keywords: Seaweeds, species diversity, marine forests**,** DNA, Atlantic

Introduction

Marine forests are widespread across the globe, providing numerous services to coastal ecosystems and economies (Wernberg & Filbee-Dexter 2019). Of concern are recently documented and projected changes to marine forests due to climate change, and the accompanying impacts to services they provide (Krumhansl et al. 2016, Assis et al. 2018, Smale et al. 2019). Safeguarding against such changes inherently depends on a thorough understanding of species diversity and biogeographic patterns within marine forests, knowledge that is unfortunately lacking or requires genetic verification in many areas of the globe.

Sequence data are critical to enhancing information regarding the distribution of marine macroalgal species diversity. Morphological identifications of macroalgae are frequently hampered by cryptic species diversity, convergent evolution, simple gross morphology, and phenotypic plasticity, issues typically resolved using sequence data (Le Gall & Saunders 2010). DNA barcoding, in particular, utilizes standardized genetic markers to assign morphological species to genetic units (Saunders 2005, Saunders & Kucera 2010). These efforts have led to numerous taxonomic revisions and biogeographic insights (e.g. Melbourne et al. 2017, Kawai et al. 2019a, 2019b, Kupper et al. 2016), and also provide critical baseline information regarding species distributions needed for monitoring ongoing range shifts in marine forests.

The coast of Norway covers more than 13 degrees of latitude in a south-north direction, and exhibits conspicuous archipelagos along most of the coast, interrupted by numerous large and small fjords. On the South-West coast of Norway, average surface temperatures in the coastal areas varies from a minimum of 4 °C in February-March to a maximum of around 16 °C in August (Armitage & Sjøtun 2017), and the macroalgal vegetation is that of a typical cold temperate flora. Studies of the algal vegetation on the southwest coast of Norway extend back to the end of the 1800's (Hansteen 1892), and Levring (1937) provided the first extensive inventory of the macroalgal composition around Bergen. Another macroalgal overview from the area around Bergen was published by Jorde (1966), and during the 1950s Jorde and Klavestad (1963) carried out an extensive study of the macroalgae of Hardangerfjord south of Bergen. The main stations of this study were re-investigated 50 years later, and results showed a significant impact of a changing climate in the area (Sjøtun et al. 2015). Warming temperatures are expected to continue impacting the area, with projected poleward shifts in seaweed communities (Bartsch et al. 2012). Some systematic work including DNA sequencing of specimens exists from Norway, especially on members of the red algal order Ceramiales (e.g. Gabrielsen et al. 2003; Skage et al. 2005), and corallines (Pardo et al. 2014). However, apart from these limited studies (e.g. Rueness 2010; Armitage & Sjøtun 2016) little DNA barcoding of macroalgae from Norway has been done.

Our objective was to DNA barcode the marine macroalgal flora in the Bergen area, and compare findings to morphological species listings as reported from the marine area within Hordaland county in Brattegard & Holte (2001). To our knowledge this is the first DNA barcode survey of Norwegian marine macroalgae, marking an important first step towards providing an updated compilation of the species present in the area and genetic data crucial to future biomonitoring and taxonomic work.

Material and Methods

Marine macroalgae were sampled from the Bergen area April 14-20 and June 3-13, 2016. The dataset was also supplemented with publicly available data for *Lithothamnion glaciale* Kjellman, collected May 1, 2008. The macroalgal flora of the area sampled corresponded to the one listed for sector 8 as defined by Brattegard & Holte (1997), an area that represents the coast of Hordaland county, spanning from 59°30' N to 60°51'N. Specimens were haphazardly collected in the intertidal or via scuba up to a max depth of 15 m (though some species were targeted for population genetic analyses separate from the current study, i.e. larger sample sizes in Table 1). Specimens were variously preserved on herbarium sheets and/or as 1 cm^2 portion of material stored in silica for DNA extraction (Saunders & McDevit 2012). Most of the press material is currently stored at the University of New Brunswick (Canada), with a subset stored at the Herbarium BG at the University of Bergen.

Several barcode markers were amplified, including the five prime end of the cytochrome c oxidase subunit I gene (COI-5P) in Rhodophytes and Phaeophyceae as per Saunders & Moore (2013) and Saunders & McDevit (2012), respectively; elongation factor *tufA* in Chlorophytes as per Saunders & Kucera (2010); and full or partial (three prime end) of the ribulose-1, 5-biphosphate carboxylase large subunit gene in Rhodophytes and Phaeophyceae as per Saunders & Moore (2013) and Daugbjerg and Andersen (1997), respectively. Primer information is provided in Table S1. PCR thermocycling regimes for respective markers followed Saunders and Moore (2013), except *tufA* (Saunders and Kucera 2010). Successful PCR products were sent to Genome Quebec for forward and reverse sequencing. Genetic data were edited in Geneious version 8.0 (www.geneious.com; Kearse *et al.* 2012). See Table S2 for a specimen list, markers sequenced, and accompanying GenBank accession numbers. Cryptic genetic groups from other areas of the globe corresponding to some of the morphological species sampled here are also presented in Table S2. Specimen info, including sampling locations, pictures, global geographical coverage of genetic groups, and sequence data can also be accessed through the Barcode of Life Data System (Ratnasingham & Hebert 2013; DOI: dx.doi.org/10.5883/DS-NORSE). Species delineations in the brown and red macroalgae were based on the assignment of Barcode Index Numbers using the Barcode of Life Data System. Barcode Index Numbers are defined using an algorithm that approximates species units by analyzing gaps in COI-5P sequence variation, corresponding to intra- and interspecific genetic variation (Ratnasingham & Hebert 2013). A similar concept was applied to the green macroalgae using *tufA* (Saunders & Kucera 2010).

A morphological species list was compiled based on listings for sector 8 in Brattegard & Holte (2001). This list was supplemented with other sources; the full morphological species list with key references are provided in Table S3. Inferred species occurrences for sector 8, as per Brattegard & Holte (2001), were not included in the morphological species lists. Morphological listings were then confirmed if sequence data matched the same barcoded species in GenBank, and the genetic group was morphologically consistent with that species. In some cases, morphological listings were linked to newly sampled genetic groups using Rueness (1977), Maggs & Hommersand (1993), Siemer & Pedersen (1995), and Brodie *et al.* (2007; indicated with [1] in Table 1). These species records are therefore confirmed for sector 8 on the basis of morphology, rather than matching sequence data with previously generated barcodes. Species were considered new records for sector 8 given one of three conditions: 1) genetic data revealed a species not listed in Table S3 ("new records for described species" in Table 1); 2) more genetic groups were recovered than the reported number of species for a given genus from sector 8; or 3) a recovered sequence did not correspond to genetic groups previously linked to reported morphospecies for a given genus from sector 8, hence ruling these morphological listings out and indicating the presence of a new record ("new records for species lacking formal description or morphospecies assignment" in Table 1). Note, species could only be considered new records for sector 8 according to the third condition if all reported morphospecies within a given genus were previously linked with genetic groups. Finally, some genetic groups represented species lacking sufficient taxonomic understanding, including sequence data in closely related species, to determine whether or not they corresponded to sector 8 records (listed as "genetic groups of uncertain morphospecies assignment and relation to reported sector 8 flora" in Table 1).

Results

In total, we generated 655 new barcode records for COI-5P, 11 for *tufA*, 41 for *rbc*L, and nine for *rbc*L-3P (Table 1). These records represented 51 species of Phaeophyceae, nine species of Chlorophyta, and 74 Rhodophyta. Of these records, there were 113 confirmed morphological species listed in the area, 14 of which represented tentative identifications pending taxonomic work (Table 1). Seventeen species represented new records for sector 8, only six of these records were linked to formal species (Table 1; Fig. 1). The final four species records represented genetic groups whose relation to the sector 8 flora remained unclear (Table 1). Seven genetic groups were linked to morphological species through the current study.

Discussion

Our work represents the first comprehensive survey of Hordaland county macroalgae using DNA barcoding, and has yielded novel insight on levels of biodiversity present in the area. Our work, however, is not without limitations. The most obvious caveat is the varying degree of uncertainty with which genetic groups have been assigned to correct morphological species.

Here, links are primarily based on observations of diagnostic features and by comparison to material from the type localities. However, some of these assignments may be subject to change. As well, due to the limited temporal and spatial coverage of our sampling, we likely missed some species that are otherwise common in certain locations or times of year. For instance, genetic groups corresponding to *Petalonia* and *Scytosiphon* were recovered, but did not correspond to the reported morphospecies *Petalonia fascia* (O.F.Müller) Kuntze and *Scytosiphon lomentaria* (Lyngbye) Link. More extensive sampling may yet recover these morphospecies, and their absence from our study does not necessarily imply their absence from sector 8.

Despite the above limitations, several findings can be highlighted from our sampling. First, the molecular data were quite congruent with the morphological listings, with the majority of the species recovered based on molecular data confirming listed morphospecies (113/134). This indicates the morphological work of taxonomists studying this flora (references in Brattegard & Holte 2001) is generally a good representation of the species diversity present in Norway. This stands in contrast to other northern systems wherein DNA barcoding has revealed considerable taxonomic confusion in marine flora, such as in the Arctic basin (e.g., Saunders & McDevit 2013; Bringloe et al. 2017; Bringloe & Saunders 2019). Nonetheless, sequence data revealed new records to sector 8. Some of these species appear to represent cryptic genetic groups within reported morphospecies, and potentially represent unrecognized species (viz. *Petalonia fascia*, *Phycodrys rubens* (Linnaeus) Batters, *Scytosiphon lomentaria*, and *Rhodophyllis divaricata* (Stackhouse) Papenfuss; Table 1). Similarly, many of the tentative molecular confirmations are subject to scrutiny given the presence of cryptic genetic groups in other areas of the globe (viz. *Asperococcus bullosus* J.V. Lamouroux, *Codium fragile* [Suringar] Hariot, *Desmarestia aculeata* [Linnaeus] J.V.Lamouroux, *Ectocarpus siliculosus* [Dillwyn]

Lyngbye, *Elachista fucicola* [Velley] Areschoug, *Halosiphon tomentosus* [Lyngbye] Jaasund, *Monostroma grevillei* [Thuret] Wittrock, *Phymatolithon lenormandii* [Areschoug] Adey, *Polysiphonia stricta* [Mertens ex Dillwyn] Greville, *Pterothamnion plumula* [J.Ellis] Nägeli, *Vertebrata fucoides* [Hudson] Kuntze; Table S2). In the previous examples it has yet to be determined which of the genetic partners represents the bona fide species and which requires a different name. In contrast, recent taxonomic work has resolved identifications in some cryptic species groups, including two morphospecies reported here (Phaeophyceans *Chorda filum* [Linnaeus] Stackhouse and *Eudesme borealis* H.Kawai, T.Hanyuda & A.F.Peters; Kawai et al. 2019a, 2019b). Alternatively, some of the new species records to sector 8 may correspond to morphological listings from adjacent sectors and, as such, the full list of Norwegian species should be considered during future taxonomic work. Cumulatively, these cases further highlight the utility of sequence data to unmask hidden diversity and inform taxonomic revisions.

The need for taxonomic work can be extended to the set of genetic records for which morphological assignment and relation to the sector 8 flora remained uncertain. Further sampling and linking of genetic groups to morphospecies would shed light on these records, some of which are likely to confirm additional morphospecies from sector 8. In particular, the Rhodophyte *Hildenbrandia rubra* (Sommerfelt) Meneghini has its type locality in Nordland (north of Bergen), however, more sampling is required to determine if our genetic group corresponds to this morphospecies, as several dozens of genetic groups throughout the Northern Hemisphere are assignable to *H. rubra* (Table S2). The genetic record tentatively identified as Tilopteridalean sp. further showcases the limited taxonomic understanding in crustose macroalgal species.

Interesting biogeographic patterns can also be noted for several Rhodophytes from our sampling. *Coccotylus brodiei* (Turner) Kützing and *Erythrodermis traillii* (Holmes ex Batters) Guiry & Garbary were previously inferred from sector 8 but are verified for the first time here (Fig. 1, Table S2). Known ranges can also be extended northwards in *Fredericqia deveauniensis* Maggs, L.Le Gall, Mineur, Provan & G.W.Saunders and *Meredithia microphylla* (J.Agardh) J.Agardh, which were previously reported from more southerly European locations (Guiry & Guiry 2019). Also worth noting is the presence of several species also reported from the Bering Sea, indicating the Norwegian flora is characterized by a number of broadly distributed cold-tolerant species (viz. *Coccotylus truncatus* [Pallas] M.J.Wynne & J.N.Heine, *E. borealis*, *Fucus distichus* Linnaeus, *Haplospora globosa* Kjellman, *Lithothamnion glaciale* Kjellman, *Odonthalia dentata* [Linnaeus] Lyngbye, *Planosiphon zosterifolius* [Reinke] McDevit & G.W.Saunders, *Ulva fenestrata* Postels & Ruprecht previously reported from the Arctic as *Ulva lactuca* Linnaeus, *Urospora* sp.; Table 1; Table S2; Saunders & McDevit 2013, Bringloe et al. 2019). This pattern was summarized for cold temperate and Arctic floras by Lüning in 1990, however, subsequent genetic surveys indicate substantial population differentiation across these ranges, some of which may represent incipient speciation (Saunders & McDevit 2013, Bringloe & Saunders 2018).

On a final note, a large portion of the sector 8 marine flora remains to be sequenced. Morphological listings indicated 117 species of Phaeophycae, 70 species of Chlorophyta, and 149 species of Rhodophyta are present in the area (Table S3); of these, we genetically confirmed the presence of 43 brown (37%), seven green (10%), and 62 (42%) red macroalgal species, only a third of all the morphological species listed. Many of the remaining species are microscopic, and will require considerable efforts to sample and possibly cultivate for subsequent DNA analysis. Return efforts to DNA barcode the flora of sector 8, and indeed the entirety of the coastline of Norway, are therefore expected to be productive, further assigning genetic data to morphospecies and unmasking cryptic diversity or species complexes in need of taxonomic revision.

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Table 1. Summary of results from a DNA barcode survey of marine flora in Bergen and surrounding area (sector 8). An asterisk indicates species wherein the species name has been updated since Brattegard & Holte 2001; [1]indicates species wherein the genetic group was linked to the morphological listing through the current study. Note some molecular listings are tentative, pending further taxonomic work.

Species	Sample sizes and notes
Confirmed morphological listings	
Chlorophyta	
Acrosiphonia arcta (Dillwyn) Gain*	n=1: taxonomic name updated from *Spongomorpha arcta* (Dillwyn) Kützing.
Codium fragile (Suringar) Hariot	Tentative; n=3: this species occurs as two genetic groups in the North Atlantic. The genetic group sampled here also occurs in the Northwest Atlantic, while a second genetic group is confirmed from the Northeast Atlantic and the Northeast Pacific (Table S2).
Monostroma grevillei (Thuret) Wittrock	Tentative; n=1: this species occurs as two genetic groups, one in the North Pacific and one in the North Atlantic; taxonomic work is needed to determine which is true *M. grevillei*.
Prasiola furfuracea (Mertens ex Hornemann) Trevisan	Tentative; n=1: taxonomic work is needed to determine if *P. furfuracea* differs from *Prasiola borealis* M.Reed (*tufA* differs at a single site across 574 bp); if these species are the same, *P. furfuracea* has nomenclatural priority (Moniz *et al.* 2014).
Spongomorpha aeruginosa (Linnaeus) Hoek	n=1
Ulva intestinalis Linnaeus*	n=1: taxonomic name updated from *Enteromorpha intestinalis* (Linnaeus) Nees.
Ulothrix flacca (Dillwyn) Thuret	n=1
Ulva fenestrata Postels & Ruprecht*	n=1: specimens from this region were previously incorrectly identified as *Ulva lactuca* Linnaeus.
Phaeophyceae	
Acrothrix gracilis Kylin	n=1

Alaria esculenta (Linnaeus) Greville	n=21
Ascophyllum nodosum (Linnaeus) Le Jolis	n=1
Asperococcus bullosus J.V. Lamouroux*	Tentative; n=5: data revealed distinct genetic groups assignable to this morphological listing for our collections from Australia versus Norway. Taxonomic name updated from *Asperococcus turneri* (J.E.Smith) W.J.Hooker.
Asperococcus fistulosus (Hudson) Hooker	n=3
Chaetopteris plumosa (Lyngbye) Kützing*	n=7: taxonomic name updated from *Sphacelaria plumosa* Lyngbye.
Chorda filum (Linnaeus) Stackhouse	n=7
Chordaria flagelliformis (O.F.Müller) C.Agardh	n=3
Cladostephus spongiosum (Hudson) C.Agardh	n=2
Cutleria multifida (Turner) Greville	n=1
Desmarestia aculeata (Linnaeus) J.V.Lamouroux	Tentative; n=9: two distinct and geographically widespread COI-5P genetic groups are assignable to this morphological species (Table S2). Our Norway collections are assignable to only one of those genetic groups; taxonomic work is needed.
Dictyota dichotoma (Hudson) J.V.Lamouroux	n=5
Ectocarpus fasciculatus Harvey	n=6
Ectocarpus siliculosus (Dillwyn) Lyngbye	Tentative; n=1: three COI-5P genetic groups are assignable to this morphospecies (Table S2). The Norway specimen joins a genetic group with collections from British Columbia and the Atlantic Provinces, Canada.
Elachista fucicola (Velley) Areschoug	n=1: two COI-5P genetic groups are assignable to this morphological listing, one thus far confined to the northeast Pacific and the other the Canadian Arctic and Atlantic Provinces, as well as New England, USA. This specimen from Norway joins the North Atlantic/Arctic group, which likely represents bona fide *E. fucicola*.
Fucus distichus Linnaeus	n=1
Fucus serratus Linnaeus	n=2
Fucus spiralis Linnaeus	n=2: recent genomic work continues the ongoing debate regarding recognition of this genetic group at the species level (Alvarez et al. 2018).

Fucus vesiculosis Linnaeus	n=2
Halidrys siliquosa (Linnaeus) Lyngbye	n=4
Halosiphon tomentosus (Lyngbye) Jaasund	Tentative; n=1: two COI-5P genetic groups are assignable to this morphological listing (Table S2). One extends from Nome, Alaska to Churchill, Hudson Bay, while the other is found in the Canadian Atlantic Provinces, as well as New England, USA (Bringloe & Saunders 2019). This specimen from Norway joins the North Atlantic group.
Haplospora globosa Kjellman	n=1
Himanthalia elongata (Linnaeus) S.F.Gray[1]	n=2
Hincksia hincksiae (Harvey) P.C.Silva	n=1
Isthmoplea sphaerophora (Carmichael) Gobi	n=1
Laminaria digitata (Hudson) J.V.Lamouroux	n=6
Laminaria hyperborea (Gunnerus) Foslie	n=15
Leathesia marina (Lyngbye) Decaisne*	n=2: taxonomic name updated from *Leathesia difformis* (Linnaeus) Areschoug.
Mesogloia vermiculata (Smith) S.F.Gray	n=2
Myrionema strangulans Greville	n=1
Pelvetia canaliculata (Linnaeus) Decaisne & Thuret	n=1
Planosiphon zosterifolius (Reinke) McDevit & G.W.Saunders*	n=1: taxonomic name updated from *Petalonia zosterifolia* (Reinke) Kuntze.
Punctaria latifolia Greville	n=1
Pylaiella littoralis (Linnaeus) Kjellman[1]	n=1
Pylaiella varia Kjellman[1]	n=2
Saccharina latissima (Linnaeus) C.E.Lane, C.Mayes, Druehl & G.W.Saunders*	n=14: taxonomic name updated from *Laminaria saccharina* (Linnaeus) Lamouroux.
Saccorhiza polyschides (Lightfoot) Batters	n=1
Sargassum muticum (Yendo) Fensholt	n=3

Spermatochnus paradoxus (Roth) Kützing	n=1
Sphacelaria cirrosa (Roth) C.Agardh	n=5
Spongonema tomentosum (Hudson) Kützing	n=3
Stictyosiphon soriferus (Reinke) Rosenvinge	n=1
Striaria attenuata (Greville) Greville	n=2
Rhodophyta	
Aglaothamnion tenuissimum (Bonnemaison) Feldmann-Mazoyer	n=1
Ahnfeltia plicata (Hudson) Fries	n=18
Bangia fuscopurpurea (Dwillwyn) Lyngbye*	Tentative; n=1: taxonomic work continues for this genus. Specimens from this region were previously incorrectly identified as *Bangia atropurpurea* (Roth) C.Agardh.
Bonnemaisonia asparagoides (Woodward) C.Agardh	n=3
Bonnemaisonia hamifera Hariot	n=4
Carradoriella elongata (Hudson) A.M.Savoie & G.W.Saunders*	n=7: taxonomic name updated from *Polysiphonia elongata* (Hudson) Sprengel.
Catenella caespitosa (Withering) L.M.Irvine[1]	n=1
Ceramium pallidum (Kützing) Maggs & Hommersand	n=5
Ceramium secundatum Lyngbye	n=3
Ceramium shuttleworthianum (Kützing) Rabenhorst	n=1
Ceramium virgatum Roth*	n=5: taxonomic name updated from *Ceramium nodulosum* (Lightfoot) Ducluzeau.
Chondrus crispus Stackhouse	n=6
Chylocladia verticillata (Lightfoot) Bliding[1]	n=6
Coccotylus truncatus (Pallas) M.J.Wynne & J.N.Heine	n=1

Corallina officinalis Linnaeus	n=5
Cryptopleura ramosa (Hudson) L.Newton	n=5
Cystoclonium purpureum (Hudson) Batters	n=13
Dasysiphonia japonica (Yendo) H.-S.Kim	n=10
Delesseria sanguinea (Hudson) J.V.Lamouroux	n=12
Dilsea carnosa (Schmidel) Kuntze	n=5
Dumontia contorta (S.G.Gmelin) Ruprecht	n=1
Erythrodermis traillii (Holmes ex Batters) Guiry & Garbary	n=3: this species was previously inferred from sector 8 (Brattegard & Holte 2001).
Euthora cristata (C.Agardh) J.Agardh*	n=29: taxonomic name updated from *Callophyllis cristata* (C.Agardh) Kützing.
Gaillona seposita (Gunnerus) Athanasiadis*	n=1: taxonomic name updated from *Aglaothamnion sepositum* (Gunnerus) Maggs & Hommersand.
Gelidium spinosum (S.G.Gmelin) P.C.Silva	n=3
Gloiosiphonia capillaris (Hudson) Carmichael	n=1
Griffithisia corallinoides (Linnaues) Trevisan	n=3
Halarachnion ligulatum (Woodward) Kützing[1]	n=1
Haraldiophyllum bonnemaisonii (Kylin) A.D.Zinova	n=1
Heterosiphonia plumosa (J.Ellis) Batters	n=2
Leptosiphonia brodiei (Dillwyn) A.M.Savoie & G.W.Saunders*	n=2: taxonomic name updated from *Polysiphonia brodiei* (Dillwyn) Sprengel.
Leptosiphonia fibrillosa (Dillwyn) A.M.Savoie & G.W.Saunders*	n=6: taxonomic name updated fro *Polysiphonia fibrillosa* (C.Agardh) Sprengel.
Lithothamnion glaciale Kjellman	n=4
Lomentaria clavellosa (Lightfoot ex Turner) Gaillon	n=13
Lomentaria orcadensis (Harvey) Collins[1]	n=1
Mastocarpus stellatus (Stackhouse) Guiry	n=5

Membranoptera alata (Hudson) Stackhouse	n=7
Metacallophyllis laciniata (Hudson) A.Vergés & L.Le Gall*	n=13: taxonomic name updated from *Callophyllis laciniata* (Hudson) Kützing.
Nitophyllum punctatum (Stackhouse) Greville	n=2
Odonthalia dentata (Linnaeus) Lyngbye	n=26
Osmundea oederi (Gunnerus) G.Furnari	n=2
Osmundea pinnatifida (Hudson) Stackhouse	n=2
Palmaria palmata (Linnaeus) F.Weber & D.Mohr	n=3
Phycodrys rubens (Linnaeus) Batters	Tentative; n=45: given the presence of two genetic groups potentially corresponding to *P. rubens*, name assignment is tentative pending taxonomic work. Regardless it should apply to one of the two genetic groups that we have uncovered in this flora (see *Phycodrys* sp. below).
Phyllophora crispa (Hudson) P.S.Dixon	n=9
Phyllophora pseudoceranoides (S2.G.Gmelin) Newroth & A.R.A.Taylor ex P.S.Dixon & L.M.Irvine	n=16
Phymatolithon lenormandii (Areschoug) Adey	Tentative; n=1: two COI-5P genetic groups are assignable to this species, this sequence from Norway and sequences for collections from the Northwest Atlantic (Table S2).
Plocamium lyngbyanum Kützing*	n=5: specimens from this region were previously incorrectly identified as *Plocamium cartilagineum* (Linnaeus) Dixon.
Polyides rotundus (Hudson) Gaillon	n=2
Polysiphonia stricta (Mertens ex Dillwyn) Greville	Tentative; n=7: three COI-5P genetic groups are assignable to this morphospecies with specimens from Norway joining a genetic group confined to the North Atlantic (Table S2). Taxonomic work is needed.
Porphyra umbilicalis Kützing	n=2
Pterothamnion plumula (J.Ellis) Nägeli	Tentative; n=4: two COI-5P genetic groups are assignable to this morphospecies, taxonomic work is needed (Table S2).
Ptilota gunneri P.C.Silva, Maggs & L.M.Irvine	n=39
Pyropia leucosticta (Thuret) Neefus & J.Brodiei*	n=4: taxonomic name updated from *Porphyra leucosticta* Thuret.
Rhodomela confervoides (Hudson) P.C.Silva	n=25

Rhodomela lycopodioides (Linnaeus) C.Agardh	n=19
Rhodophyllis divaricata (Stackhouse) Papenfuss	Tentative; n=6: four COI-5P genetic groups are potentially assignable to this morphospecies (Table S2), two of which were recovered here. Taxonomic work is needed.
Seirospora interrupta (Smith) F.Schmitz	n=1
Vertebrata byssoides (Goodenough & Woodward) Kuntze*	n=1: taxonomic name updated from *Brongniartella byssoides* (Goodenough & Woodward) Schmitz.
Vertebrata fucoides (Hudson) Kuntze*	Tentative; n=2: two COI-5P genetic groups are assignable to this morphospecies, one confined to the Northwest Atlantic and the other on both sides of the North Atlantic, the specimens from Norway joining the latter group (Savoie & Saunders 2019; Table S2). Taxonomic name updated from *Polysiphonia fucoides* (Hudson) Greville.
Vertebrata lanosa (Linnaeus) T.A.Christensen*	n=4: taxonomic name updated from *Polysiphonia lanosa* (Linnaeus) Tandy.
Wildemania amplissima (Kjellman) Foslie	n=2
New records for described species	
Phaeophyceae	
Eudesme borealis H.Kawai, T.Hanyuda & A.F.Peters	n=2: though *Eudesme virescens* (Carmichael ex Berkeley) J.Agardh occurs in sub-boreal European waters, our genetic data matched the newly established and broadly distributed *Eudesme borealis* H.Kawai, T.Hanyuda, A.F.Peters (Kawai et al. 2019b).
Scytosiphon promiscuus McDevit & G.W.Saunders	n=1: this species was recently described by McDevit & Saunders (2017).
Rhodophyta	
Coccotylus brodiei (Turner) Kützing	n=31: though reported from Northern Norway (Guiry & Guiry 2019), these are the first genetically verified records from the Bergen area.
Fredericqia deveauniensis Maggs, L.Le Gall, Mineur, Provan & G.W.Saunders	n=1: this species was previously reported from more southerly European areas (Guiry & Guiry 2019).
Meredithia microphylla (J.Agardh) J.Agardh	n=1: this species is previously reported from more southerly European areas (Guiry & Guiry 2019).
Titanoderma macrocarpum (J.V.Lamouroux) Nägeli	n=1: see Saunders (2019) for taxonomic notes.
New records for species lacking formal description or morphospecies assignment	

Chlorophyta	
Urospora sp.	n=1: the genetic group recovered did not match *Urospora penicilliformis* (Roth) Areschoug, the only species of *Urospora* reported for the area; rather, this genetic group most closely matched *Urospora wormskioldii* (Mertens ex Hornemann) Rosenvinge (97%). This genetic group was previously reported as *Urospora* sp. 2Nome from Nome, Alaska (Bringloe and Saunders 2019; Table S2); taxonomic work is needed.
Phaeophyceae	
Ectocarpus sp.	n=1: a third *Ectocarpus* genetic group was recovered, despite only two being listed in the flora.
Myriotrichia sp.	n=1: this newly sampled genetic group does not match *Myriotrichia clavaeformis* Harvey, leaving only *Myriotrichia repens* Hauck, also reported in the area, as a putative match. However, microscopic examination of the host brown alga did not reveal the latter species leaving the identification uncertain but indicating the presence of a new record.
Pelatonia sp.	n=1: this genetic group does not correspond to *Petalonia fascia*, the only species of *Petalonia* reported and genetically confirmed in the area (AB860189). Taxonomic work is needed to assign a species name.
Scytosiphon sp.	n=3: another *Scytosiphon* genetic group was recovered, which also did not correspond to *Scytosiphon lomentaria* (Lyngbye) Link, the only reported species of *Scytosiphon* reported from the area. Considerably more sampling is necessary given the diversity of *Scytosiphon* spp. in the North Atlantic (McDevit & Saunders 2017).
Rhodophyta	
Ceramium spp.	n=2: a further two new genetic groups for *Ceramium* were recovered. Based on *rbc*L data, one is closely related to *C. secundatum* (99%; also reported from France as *Ceramium* sp. MAR5), while the other is a close match to *Ceramium pallidium* (Kützing) Maggs & Hommersand (98%). The genetic groups recovered here also do not match published *rbc*L data for the other species of *Ceramium* listed for the area (Gabrielsen *et al*. 2003; Wolf *et al*. 2011; Hughey & Boo 2016). As such, two new records for *Ceramium* are inferred here, but taxonomic work is needed to assign a species name or description.

Lomentaria sp.	n=1: this genetic group is a close match to *L. clavellosa* (based on COI-5P; 97%). *Lomentaria articulata* (Hudson) Lyngbye is listed for the area (Brattegard & Holte 2001), but is currently linked to a different genetic group, indicating the presence of a new species.
Phycodrys sp.	n=22: this genetic group was originally reported from Europe by van Oppen et al. (1995). Taxonomic work is needed to assign a species name, and to determine whether the genetic group above has been correctly assigned to *P. rubens*.
Polysiphonia sp.	n=6: this genetic group corresponds to *Polysiphonia* sp. 23GWS, which was previously limited to two specimens from Rhode Island, USA, and one from the Bay of Fundy, New Brunswick, Canada (Savoie & Saunders 2019). In addition to *P. stricta*, *Polysiphonia hemisphaerica* Areschoug is also reported from sector 8, however, our sequence is a distant match to published COI-5P and *rbc*L data for this species (Rueness 2010; Díaz-Tapia *et al.* 2018). As such, a new record for *Polysiphonia* is inferred here, but taxonomic work is needed to assign a species name or description.
Rhodophyllis sp.	n=5: as with *Phycodrys*, multiple genetic groups corresponding to a single morphological listing were recovered, in this case potentially corresponding to *R. divaricata*. Taxonomic work is needed to assign a species name to the multiple groups listed in Table S2, and to determine whether the correct genetic group has been assigned to *R. divaricata*.
Genetic groups of uncertain morphospecies assignment and relation to reported sector 8 flora	
Phaeophyceae	
Lithoderma sp.	n=2: *Pseudolithoderma extensum* (P.Crouan & H.Crouan) S.Lund has been reported from Norway, but our genetic group allies closer to species that we have tentatively assigned to *Lithoderma* (Table S2). This genetic group is potentially assignable to *Lithoderma fatiscens* Areschoug, which is reported from Swedish and Arctic waters (Rueness 1977). Taxonomic work is needed.
Tilopteridalean sp.	n=1: it remains unclear whether or not this crustose specimen corresponds to any of the species listed by Brattegard & Holte (2001).
Rhodophyta	
Hildenbrandia sp.	n=1: several dozens of COI-5P genetic groups are assignable to

	Hildenbrandia rubra (Sommerfelt) Meneghini (examples provided in Table S2). As such, we cannot be certain if this genetic group corresponds to *H. rubra* or represents a new record for sector 8. We do note, however, that *H. rubra* has its type locality in Nordland (north of Bergen; Guiry & Guiry 2019). More sampling and substantial taxonomic work is needed in this genus.
Rhodomelacean sp.	n=4: this genetic group allies to the tribe Pterosiphonieae based on both COI-5P and *rbc*L, but insufficient sequence data and taxonomic information exists to determine if this genetic group corresponds to any of the species listed by Brattegard & Holte (2001).

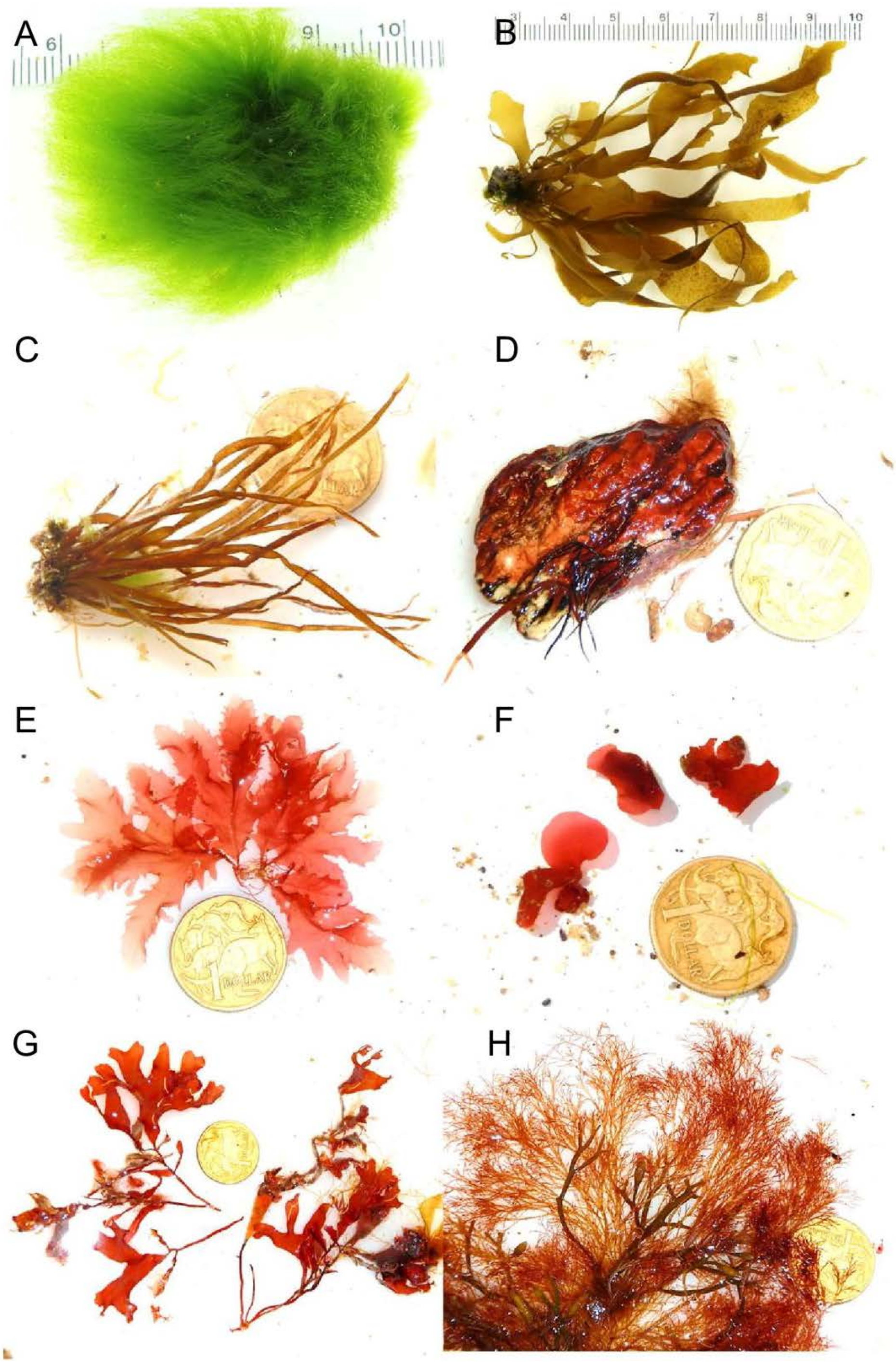

Figure 1. Marine macroalgae sampled from sector 8, Bergen area, April 14-20 and July 3-13, 2016. Confirmed record: A) *Acrosiphonia arcta* (2016_BIO309A_61); new records: B) *Petalonia* sp. (2016_BIO309A_57); C) *Scytosiphon* sp. (GWS040911); D) *Hildenbrandia* sp. (GWS040997); E) *Phycodrys* sp. (GWS040070); F) *Meredithia microphylla* (GWS040886); G) *Coccotylus brodiei* (GWS040736); H) *Ceramium* sp. (GWS040811). A cm ruler is used for scale, or otherwise an Australian dollar (diameter of 2.5 cm).